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UNITED STATES DEPARTMENT OF AGRICULTURE

FOREST SERVICE

PACIFIC N. W. FOREST AND RANGE EXPERIMENT STATION

PROGRESS REPORT

STUDIES OF THE BIOLOGY AND CONTROL OF THE BALSAM WOOLLY APHID

1957 SEASON

By

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Pacific Northwest Forest & Range Exp. Station
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Chief, U. S. Forest Service   March 13, 1958

R. W. Cowlin, Director   By:

RI-NW SUCKING INSECTS, Reports (chermes)

Enclosed are one copy each of two progress reports on chermes research in 1957. One by Wright and Mitchell, describes details of the colonization of the European predator *Aphidoletes thompsoni* Moehn in Oregon and Washington; the other, by Mitchell, is a summary of all biological work done during the season on Chermes. Both projects were under the leadership of K. H. Wright.

The reports are being sent air mail in case they are needed as references in discussing cooperative agreement research projects with Director Cowlin. He indicated that following the RF and D meeting, he planned to review with you the progress to date on the Chermes project at Oregon State College, and the bark beetle disease work being done by Thomas at Berkeley.

Approximately 30 copies of the *Aphidoletes* report were processed, and several will be sent to the Canadians. Dr. Blair McGugan, at the work conference in Corvallis, specifically requested that a copy be sent to Dr. Prebble's office as an aid in developing a colonization program for *Aphidoletes* in Newfoundland this year. Only 8 copies of the Chermes report were typed. Aside from the enclosed copy, they are being distributed only to men actually working on the insect in this region, and to the Northeastern Station.

Enclosures (2)

STUDIES OF THE BIOLOGY AND CONTROL
OF THE BALSAM Woolly APHID
By
R.G. mitchell

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SUMMARY

In 1957, studies of the biology and control of the balsam woolly aphid (*Chermes piceae* Ratz) were carried out by the Pacific Northwest Forest and Range Experiment Station. In addition, a cooperative 2-year research project on biological control of the insect was undertaken with Oregon State College. The report summarizes progress made on these sutdies in 1957.

In July, some 10,000 larvae and puparia of the European dipterous predator *Aphidoletes thompsoni* Moehn were kindly provided by the Canadian Department of Agriculture for rearing and colonization in Western Oregon and Washington. Some 1830 adult predators were reared and released at 3 locations in the two states. It is believed that first generation larval progeny of the predators has been collected at 2 release points.

Studies of native insect predators and other associated arthropods of *Chermes* disclosed that a syrphid, *Cnemodon rita* Curran, was generally present throughout the infested zone. Despite its abundance, it does not appear to be highly effective in controlling host populations. Other predators collected, but as yet unidentified, included a syrphid and a hemerobiid. Other suspected predators found included 3 species of neuropterons and 3 species of mites.

Life history studies in 1957 showed that *C. piceae* produced 2 generations at Black Rock and Willamette Pass, in Oregon, and 3 or more at Wind River in Washington. Total egg production per adult varied with the species of host tree on which they were produced. Motile larvae

were found to be readily dispersed by air currents; recovery on glass plates varied directly with distance from infested host trees. Wind born larvae were consistently collected 80 feet from the nearest host tree. To date, thirteen species of native and exotic species of _Abies_ have been found infested with _C_. _piceae_ in Oregon and Washington.

Chermes-damaged trees on cooperative trend plots in Pacific silver fir sawtimber stands in the Toutle River drainage of Washington showed considerable recovery in 1957. Even trees that were considered almost dead in 1956, put out some new growth in 1957. Of the 300 trees that were tagged and rated as to damage in 1954, only 4 have died and about 30 percent of them have improved in crown condition. Tree killing in many other areas, however, continues high.

INTRODUCTION

The balsam woolly aphid, Chermes piceae Ratz. is currently the most destructive forest insect pest in the Pacific Northwest. Its most frequently attacked hosts are subalpine fir, Abies lasiocarpa (Hook.) Nutt., and Pacific silver fir, Abies amabilis (Dougl.) Forbes. At lower elevations the pest also attacks grand fir, Abies grandis (Dougl.) Lindl. In addition to forest trees, chermes has been observed infesting several exotic species of Abies.

Serious damage on silver fir caused by the balsam woolly aphid was first discovered in southeastern Washington in 1954. Further investigation the same year revealed an infestation covering 276,160 acres, some in Oregon. The following years revealed a continual increase in the size of the infestation, both in Oregon and Washington. In 1957 the area of the epidemic reached an all-time high of nearly 600,000 acres.

In the past, western true firs have generally had a low commercial value. In recent years, however, their value has been greatly enhanced by an increased activity in the region's pulp and paper industry. This activity, coupled with a serious log shortage in western Washington, has made silver fir a particularly important species. The high altitude alpine fir is not yet considered a commercial species, although its value as a watershed cover and for recreation is high.

Because no control methods for the insect are known, the only recommendation available to forest land managers has been to salvage the affected timber as rapidly as possible. However, in an attempt to develop control measures, the Pacific Northwest Forest and Range Experiment Station in 1957 began intensive investigations of the biology and control of the balsam woolly aphid. To further speed up research, a 2-year cooperative project was undertaken during the season with Oregon State College to explore the possibilities of biological control. The purpose of the following report is to describe the procedures, and to relate the observations and results, of the first seasons work by the cooperators.

Those concerned with conduct of the project to date in addition to the writer are: Dr. J. A. Rudinsky, Project Leader representing Oregon State College; K. H. Wright, Project Leader representing the Experiment Station; P. E. Buffam, field assistant; and D. K. Costello, laboratory assistant.

STUDY OBJECTIVES

Long-term objectives of the cooperative studies of the balsam woolly aphid are: (1) To determine the habits of the insect, (2) to assess the effectiveness of biotic factors, and (3) to develop a biological control program. Achievement of the main objectives will be approached from two different directions: (1) By a study of the biology and behavior of *C. Piceae*, and (2) by a study of the effectiveness of both introduced and native predators.

So as to proceed in an orderly manner, the over-all problem is broken down into its various components and to each facet secondary objectives are assigned. Different components will then be studied each year until their objectives are met. Study objectives in 1957 [1] were:

1. To colonize the European predator Aphidoletes thompsoni Mohn. (Diptera: Itonididae)in the Pacific Northwest.

2. To obtain and identify as many as possible of the native predators that prey on chermes [2] populations in the Pacific Northwest and to evaluate their importance in controlling chermes populations.

3. To determine the number of chermes generations per season on Abies amabilis and A. lasiocarpa, the stages present at different times of the year, and the reproductive rate and potential.

4. To find if there is an observable difference in behavior of chermes populations on various host species and in different areas.

5. To determine the general distribution of chermes in Oregon and Washington, particularly the furthermost points of spread.

6. To determine the apparent susceptibility and nature of "gouting" on the various species of Abies.

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[1] Reference is made to the season's work plan, entitled, Work Plans for Balsam Woolly Aphid Research, Season of 1957 by K. H. Wright and R. G. Mitchell. PNW Forest and Range Experiment Station, Portland, Oregon. July 1, 1957.

[2] Hereafter in the report the generic term Chermes will be used as a common name and therefore not underlined.

7. To determine the rate of decline of chermes-damaged Abies on existing plots, to evaluate and summarize data collected to date, and to assess the desirability of installing future plots and possible data to be taken.

INTRODUCTION OF APHIDOLETES THOMPSONI

A cooperative plan for importing and establishing in North America foreign predators of the balsam woolly aphid was instituted this year between Science Service, Canadian Department of Agriculture, and the Forest Service, U. S. Department of Agriculture. The itonidid *Aphidoletes thompsoni*, was the first predator made available to the Pacific Northwest.

Methods and Procedures of Rearing and Release

Ten thousand *A. thompsoni* from eastern Slovakia via Vienna, Austria and Belleville, Ontario arrived in Portland, Oregon on July 1. The predators were shipped by air freight and were packed in damp sand which was in turn placed in cotton stoppered vials. Inspection upon their arrival revealed that most of the lot were still in the larval stage.

To rear the predators, roughly equal amounts of sand were placed in 16 rearing cages representing 3 types of rearing containers: Melrose boxes, pint-size ice cream cartons, and quart-size ice cream cartons. Each rearing container was fitted with a four-inch shell-vial to collect the adult predators and associated insects as they emerged. Periodically the emergence vials containing adults were removed from the rearing boxes. Parasites and other associated arthropods were then asperated off and the remaining itonidids were sexed, counted and placed in cold storage. After two to three hundred adults had been accumulated they were taken to the field for release.

The predators were transported to the field in ice-packed boxes. The two release points in Oregon were Black Rock and Corvallis. In Washington they were released in three different areas in the Toutle River drainage. Most of the predators were freed in sleeve cages attached to chermes-infested trees having bole attacks. The purpose of the cages was to prevent rapid spread and to keep the insects in close proximity with their prey. In addition to the cage releases, a total of about 700 predators were released free at the bases of bole-infested trees.

Results of Rearing and Release

Some 1830 adult *Aphidoletes* were reared and released. The best rearing containers proved to be two ice cream cartons resting in damp sand. This method produced an average of 31.3 insects per gram of soil while the wooden boxes yielded only 8.42 insects per gram, and the pint-size containers 10.5. The two latter types were not placed on damp sand. It was found that keeping the predators at a temperature of about 45° F. materially prolonged their life.

Checks four weeks later at the Black Rock release points revealed itonidid larvae believed to be *Aphidoletes thompsoni*. These were cage releases. Later in the summer, itonidid larvae were also recovered at two release points in the Toutle River drainage. One of these was a cage release and the other was free. Attempts to rear the larvae to adults have so far met with failure. Absolute proof that the larvae were *A. thompsoni* is therefore not yet possible.

For additional details on the rearing and release of Aphidoletes, reference is made to a special report now being prepared on that subject.[1]

IDENTIFICATION AND EVALUATION OF NATIVE PREDATORS

In 1955, two predators of C. piceae, identified as Leucopis sp. near americana, and Neocnemodon sp., were recovered in the Mt. Hood area. The 1957 work was intended to reveal the presence of other predators and also their distribution and effectiveness as controlling agents of the balsam woolly aphid.

Methods and Procedures of Study

One European silver fir (Abies alba Miller), and several native silver, subalpine, and grand firs with heavy chermes bole infestations were tagged as permanent collection trees. An attempt was made to locate these trees in areas that would represent a fair cross-section of the region's infestation zone. Table 1 presents the general locations of the trees, the species represented, and approximate elevations of the study areas. After July 10 and up until the end of September, predator collections and observations were made at least every two weeks in each area. Owing to the unexpected shipment of foreign predators, it was not possible to start collections any earlier than the middle of July.

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[1] Colonization in Oregon and Washington of Aphidoletes thompsoni - An European predator of the balsam woolly aphid by K. H. Wright and R. G. Mitchell. Progress report, processed. Pacific Northwest Forest and Range Experiment Station. Portland, Oregon. Feb. 1, 1958.

Table 1. - Elevation, location, and tree species studied at predator collection areas.

Location	Tree Species	Elevation
Toutle River Drainage, Washington	*A. amabilis*	2500 - 3500
Wind River Arboretum, Washington	*A. alba* and *A. lasiocarpa*	1000
Black Rock, Oregon (Upper Warnick Creek drainage)	*A. amabilis*	2800
Corvallis, Oregon	*A. grandis*	230
Willamette Pass, Oregon	*A. lasiocarpa*	4000

Rearings to obtain the adult forms of the predators were undertaken both in the field and in the laboratory. In the field, small plastic cages (figure 1) with screened tops were used to isolate individual predators on the trees. The cages were attached to the tree by embedding them in a ring of modeling clay pressed onto the bark. In the case of those predators that pupated in the soil, small trays made of plastic screen rimmed with eight gauge wire were devised to catch the larvae as they dropped from the tree (figure 2). In the laboratory, isolated larvae were reared to pupae in screen bottomed cages set in damp sand. Once pupated, the predators were placed in gelatine capsules. The capsules were then kept in a cool, moderately moist environment until the adults emerged.

At the outset of the field season, plans were to evaluate the predators' effectiveness numerically by recording data from a series of micro-plots on the bark. That proved to involve more work and preparation than the time remaining in the field season would allow. Accordingly, the discussion on predator effectiveness will be based on observations only.

Rearing and Collecting Results

The small cages for rearing in the field proved to be quite acceptable for neuropterans. They were not so successful for syrphids which pupate in the soil. However, one advantage of caging the syrphids was that young larvae could be carried to maturity. Also, caging in the field was useful in determining if an insect was merely an associate of chermes or definitely a predator. Once it was determined that a particular species was a predator and pupated in the soil, it proved far easier to collect by attaching a tray to the base of the tree. This method of capturing the falling larvae was used quite successfully with one syrphid. It was also helpful in locating the small and hard-to-find *Aphidoletes thompsoni* larvae.

Early in the season some difficulty was experienced in laboratory rearing of syrphid adults from pupae. Conditions too damp or too dry arrested development and often killed them. Extreme moisture favored the development of fungi. Rearing in gel capsules finally proved to be the most successful method for rearing syrphid pupae.

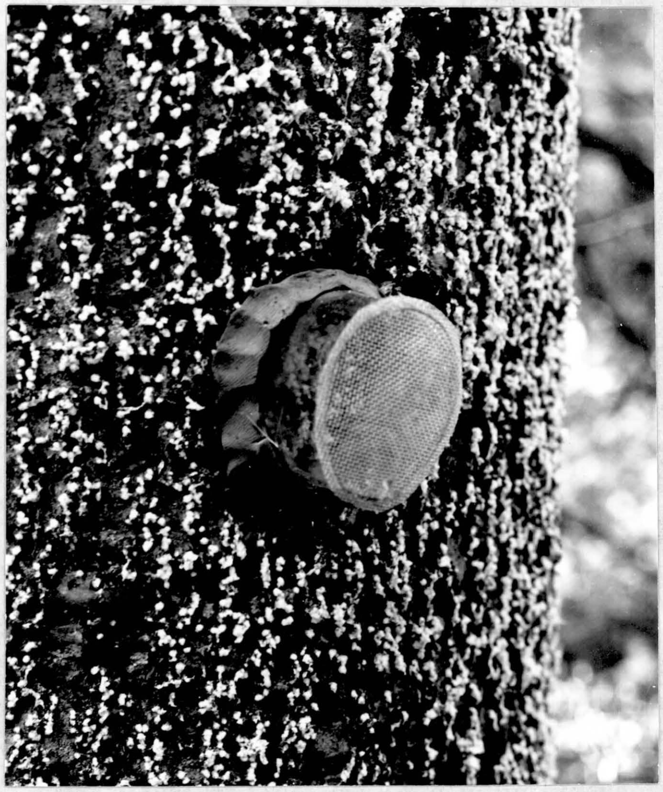

Figure 1.-Cage for rearing predators on trees in the field.

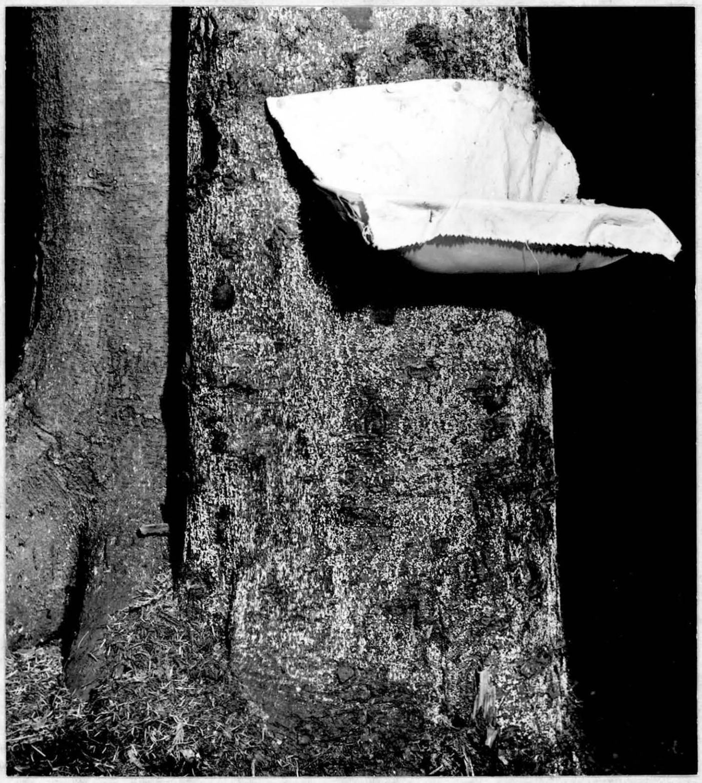

Figure 2.-Tray for catching predators that pupate in the soil.

Known and Suspected Predators Collected

Identifications are still pending on all but two of the arthropods found associated with C. piceae. The following is a list of what was found:

Known Predators

CLASS INSECTA

Diptera: Syrphidae - Cnemodon rita, Curran
Diptera: Syrphidae - 1 unidentified species
Neuroptera: Hemerobiidae - 1 unidentified species

Suspected Predators

CLASS INSECTA

Neuroptera: Chrysopidae - 2 unidentified species
Neuroptera: Raphididae - 1 unidentified species

CLASS ARACHNIDA, ORDER ACARINA

Anystis agilis (Banks) (Tronbidiformes: Anystidae)
Tronbidiformes: Tydeidae
Mesostigmata: Aceosejidae

Notes on Arthropods Collected

The following discussions summarizes the observations made on the insects and mites found associated with Chermes piceae in 1957.

Cnemodon rita (Diptera: Syrphidae) - This is the region's most abundant and possibly most important native predator of C. piceae. It appears to range throughout the entire infested zone. Adults were reared and identified from every collection point and host tree. Larvae were seen on almost every chermes-infested tree observed, regardless of how light the prey density or how isolated the tree. Appearance of the insect is shown in Figure 3.

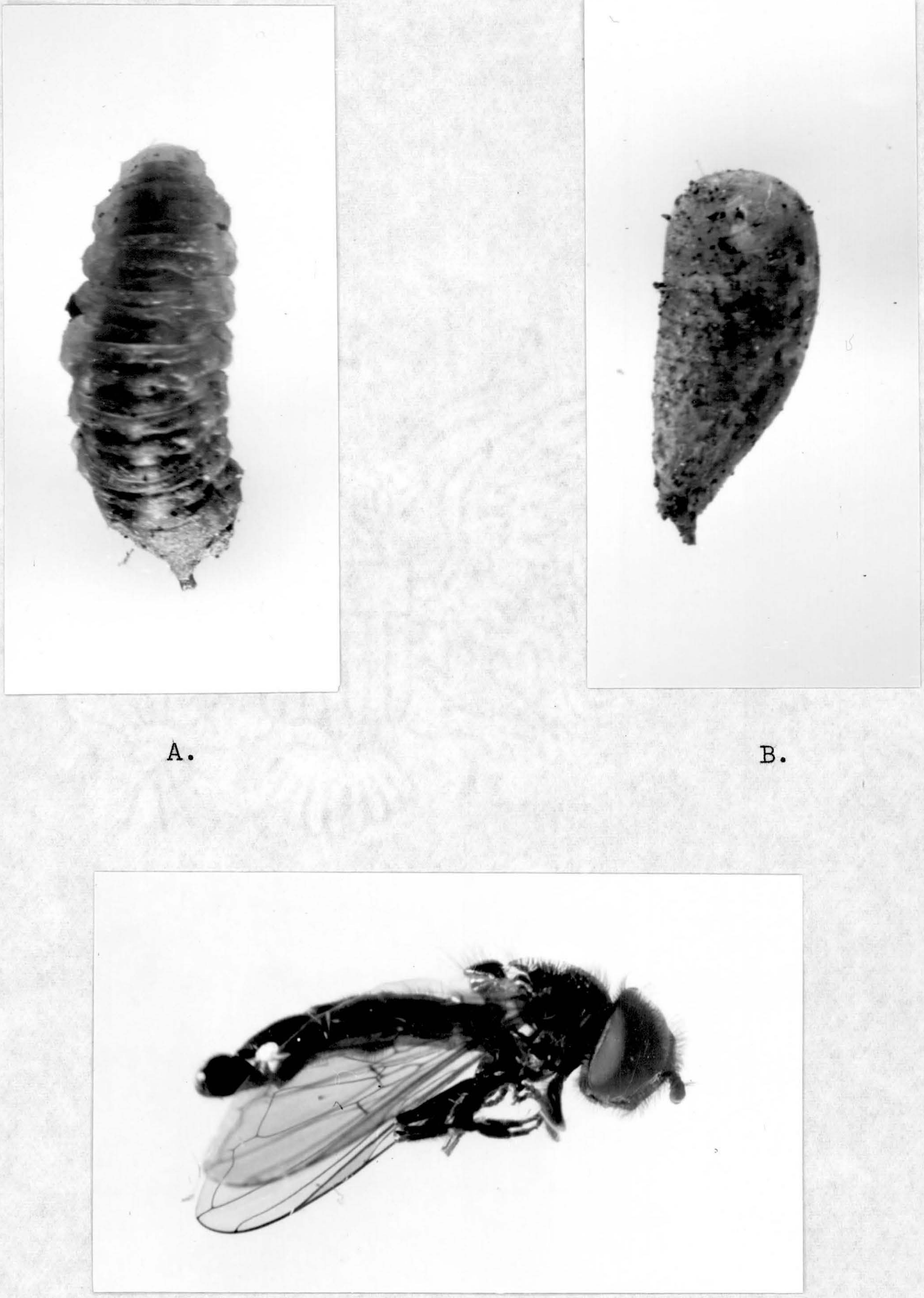

Figure 3.-The native syrphid predator *Cnemodon rita* Curran: A, prepupal larva; B, pupurium; C, adult (male)

Every chermes stage except the crawling and sessil first instar are subject to predation by *C. rita*. However, the eggs do not appear to be as acceptable to the predator as are the sistens. At the higher elevations, *Cnemodon* were observed among their prey from early July to mid-September. At Corvallis, the predator was present until early October. Pupation generally takes place in the soil, but will occasionally occur on the bole of the infested tree. For some reason, pupation on the tree was more common at Corvallis than elsewhere. Rearing notes show that under laboratory conditions it takes about 15 days for the larva to form a puparium after dropping from the tree. It then takes about 10 more days before the adult emerges. The shortest pupation period was nine days while the longest was 12. Parasitized puparia usually produced chalcids about 21 days after collection.

Syrphid eggs believed to belong to *C. rita* were found tucked in the cracks of bark and in chermes wool at almost all times of the season. This, coupled with the fact that there was never any clean break when predators completely disappeared, suggests that there are at least two overlapping generations per season.

Generally, *C. rita* appeared to be comparatively free from parasites. However, parasitism by a polyembrionic chalcid was quite heavy when the predator pupated on the tree. It is not known whether the chalcids are an important factor with those that pupate in the soil. Only two other parasites were reared -- one braconid and one ichneumonid. Both attack the larval stage.

Although *C. rita* appears to be the region's best predator, its efficiency as a controlling agent is still far from satisfactory. The chief reason for its inadequacy applies to all the other known predators of the balsam woolly aphid. That fault is that the longest part of the prey's life cycle, the diapause stage, is not acceptable to the predator. Another fault of the predator is that it does not appear in large enough numbers to significantly reduce the population before the sistens reach maturity. As a result, when the prey population is heavy, the predators appear to completely ignore the eggs in their search for sistens. The ragged appearance of the chermes population left in the wake of the searching predators produces a misleading picture of the predator's efficiency. The undestroyed eggs later hatch and become the starting point for another generation, almost as large or larger than the previous one. The final reason contributing to the inadequency of *C. rita*, and perhaps the most important, is that the feeding stages disappear just at the time when the prey's second generation reaches its peak.

Unknown Syrphid (Diptera) - This predator was observed by K. H. Wright feeding on chermes in late May at the Wind River Arboretum. The species was quite abundant during its brief appearance but not abundant enough to cause an appreciable decrease in prey population. Owing to early difficulties in rearing techniques, the adult was never obtained and consequently the species was not identified.

Unknown Hemerobiidae (Neuroptera) - This predator was observed feeding on adult sistens and eggs from the middle of July to mid-August at Willamette Pass. There appears to be but one generation per year. The species is easily reared by caging it on the tree. However, when two are caged together they will fight until one is dead.

Another species of Hemerobiidae was collected pupating on the bark of a chermes-infested tree in mid-June in the Toutle River drainage.

Chrysopidae and Raphididae (Neuroptera) - Two species of chrysopids were found pupating on the bark of infested trees. One was collected at Corvallis on July 15 and the other at Willamette Pass on August 9.

The raphidid was collected on June 17 as an adult crawling on the bark of an infested tree at Willamette Pass. Neither this insect or the chrysopid were observed actually feeding on chermes.

Anystis agilis (Tronbidifornes: Anystidae) - This mite was observed in great abundance only once -- July 30. At that time literally hundreds swarmed over the bark of an infested tree at Black Rock. Because they moved so rapidly and were so easily disturbed, it was impossible to determine whether or not they were feeding on chermes. Wharton and Baker [1] lists this family as being predaceous on other mites and small insects.

Tydeidae and Aceosejidae (Tronbidifornes and Mesostigmata) - These families of mites were found associated with C. piceae in late December at Black Rock. Wharton and Baker record both families as predaceous on mites and small insects. However, to be of any value as predators, they would have to occur earlier than December.

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[1] Wharton & Baker - An Introduction to Acarology. The MacMillan Company. New York. 1952.

CHERMES LIFE HISTORY AND BEHAVIOR STUDY

Bark samples infested with *C. piceae* were collected about once a week from three widely scattered areas. The areas were Wind River Arboretum in Washington and Black Rock and Willamette Pass in Oregon. By prior agreement, biological studies at Corvallis, Oregon and in the Toutle River drainage in Washington were to be carried on by Dr. J. A. Rudinsky and assistants at Oregon State College, and N. E. Johnson, Entomologist for Weyerhaeuser Timber Company, respectively.

From the infested bark samples and the attending observations made at the time of collections, it was hoped to determine (a) the number of chermes generations per season, (b) what stages were present at different times of the year, (c) some indication of reproductive rate and potential, and (d) any other pertinent information on the balsam woolly aphid such as dispersal or difference in feeding locations.

Seasonal History

Black Rock and Willamette Pass - In general, the life cycle in the higher elevations starts with the overwintering form of the first generation (neosisten) breaking diapause in the spring. This resumption of spring activity is characterized by a swelling of the first instar and a conspicuous glob of colorless "honeydew" at the anal end of the insect. The sistens then proceed through three moults and give rise to a second generation. The second generation repeats the pattern and throughout the fall and early winter produce the overwintering form of the first generation. Figure 4 presents a graphical picture of the seasonal occurance of the various stages.

Figure 4.-Occurrence of sistens throughout the year at Black Rock and Willamette Pass: "X" - first generation; "O" - second generation; "*" - peak in population.

```
Jan.  Feb.  Mar.  April  May  June  July  Aug.  Sept.  Oct.  Nov.  Dec.

Instar I:
XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX                XXXXXXXXXXXXXXXXXXXXXXXX
                                      OOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOO

Instars II and III:            *
                         XXXXXXXXXXXXXX
                                               *
                                           OOOOOOOOOOOOOOOOOOOOOOOOOOOOOO

Adults and Eggs:                     *
                            XXXXXXXXXXXXXXXXXX     *
                                              OOOOOOOOOOOOOOOOOOOOOOOOOOO
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The breaking of diapause has not been observed in nature by the writer, although field observations made in late May indicate that, in normal years, spring activity at these elevations starts sometime in early May. The qualification "in normal years" is added because spring temperature doubtless governs the resumption of activity. It was found, for example, that neosistens collected in late December could be forced to break diapause after being subjected to room temperature for only five days. Within a day or two after breaking diapause the sisten moults into the second instar. Apparently the cool, spring temperatures prevent rapid development in most of the intermediate instars, although an occasional adult was found in late May. Generally, however, mature sistens remained rare and did not reach their peak in population until early July.

Owing to considerable variation in rates of instar development and egg incubation, there was a great deal of over-lap in generations. From the time that the first generation adults started laying eggs, until the last collections in December, all life stages were present in some degree. The first motile larvae appeared in mid-July. After settling, these showed first signs of breaking diapause around the end of August. However, a very large percentage of the second generation neosistens did not break diapause at all and remained on the trees until the end of the season. Second and third instars literally exploded into abundance in early September and the adult population reached its peak in the latter part of the month. Oviposition began almost immediately with the appearance of the first adults and finally halted somewhere around the end of October. Eggs started hatching early in September. Thereafter, motile larvae continued to be seen until late November -- at least a full month after oviposition had halted. Apparently the temperature required for incubation is slightly lower than that required for oviposition and instar development. This is not too surprising since eggs were observed hatching in a refrigerator after they had been kept there for about a month at 45° F.

Live second and third instar larvae were present on the trees until the end of December, although they became quite rare after the middle of November. At Willamette Pass, live adults and eggs were fairly common right up until the last observation on December 28. This condition also existed on a few protected trees at Black Rock. There, heavy, fall rains cleaned the infested boles of almost every life stage except the neosisten.

<u>Wind River Arboretum</u> - Apparently the warmer spring temperatures experienced by *C. piceae* at the Wind River Arboretum permitted more rapid development than conditions at higher elevations. At least three generations were completed by fall. Figure 5 presents a chart on the occurrence of life stages present throughout the year.

Figure 5.-Occurrence of sistens throughout the year at Wind River Arboretum. "X" - first generation. "O" - second generation. "Q" - third generation. "*" - peak in population.

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=======================================================================
Jan. Feb.  Mar.  April  May  June  July  Aug.  Sept.  Oct.  Nov.  Dec.
-----------------------------------------------------------------------
Instar I:
XXXXXXXXXXXXXXXXXXXXXXXX                        XXXXXXXXXXXXXXXXXXXXXXX
                        OOOOOOOOOOOOOOO
                                      QQQQQQQQQQQQQQQQQQQQQQQQQQQQQQQQQ
-----------------------------------------------------------------------
Instars II and III: *
             XXXXXXXXXXXX
                                   *
                               OOOOOOOOOOO    *
                                          QQQQQQQQQQQQQQQQQQQQQQQQQQQQQ
-----------------------------------------------------------------------
Adults and Eggs:
                       *
                 XXXXXXXXXXXXXX      *
                               OOOOOOOOOOOOOOO
                                                    *
                                              QQQQQQQQQQQQQQQQQQQQQQQQQ
=======================================================================
```

Breaking of diapause at Wind River probably started in late March or early April. By the middle of April, second and third instars were abundant. A few adults were also present, but they did not reach their peak until mid-May. Intermediate stages of the second generation first appeared in the latter part of June and new adults became evident in early July. Late the same month, the adult population reached its peak. The third generation quickly followed the second and by the middle of September adults again were abundant.

Owing to the tremendous over-lap in generations, it was impossible to tell just what generation was or was not present after the third group of adults reached their peak. Mature sistens were present until the last observation on December 20. Another complete or partial generation may have occurred. However, no predominance of any stage other than neosistens was noted after early October.

Fecundity of *C. piceae*

From the limited observations made in 1957, no detailed assessment of the egg potential of the balsam woolly aphid was possible. However, a few figures, which give some indication of fecundity were obtained by a long and tedious method of counting the number of hatched and unhatched eggs in eight, well-developed and isolated clutches. Five of the counts were made from the first generation and three from the second. All counts were made on bark samples taken from the same host. The resultant egg counts from the first generation showed a maximum of 79, a minimum of 30, and an average of 57 eggs per clutch. For the second generation, the maximum was 67, the minimum 41, and the average 54.

Miscellaneous egg counts of unhatched eggs were made several times throughout the season. Once the eggs begin to hatch, the size of the clutch remains more or less static. Oviposition apparently is about equal to incubation in the middle of the season. The largest clutches of unhatched eggs occur in the spring when incubation is apparently slower than oviposition. Just the reverse happens in the fall. The largest number of unhatched eggs found in mid-summer was 28. Generally the number ranged from 10 to 15 eggs per clutch.

Rough egg counts suggested that the species of the host will sometimes make considerable difference in the insect's fecundity. Sistens on *Abies alba* were observed to have egg clutches containing a 100 or more eggs, while adjacent *A. lasiocarpa* revealed the more normal clutches of 60 to 70 eggs. Cursory observations seem to indicate that fecundity also varies with sistens on different hosts within species as well as between species. It appears that the chermes populations having the greatest density produce the sistens with the largest fecundity.

Dispersal

Several four-inch square glass plates covered with vaseline were placed in various infestations throughout the region. One purpose of the slides was to give some indication of the pattern and rate of chermes dispersal. Slides located at Black Rock and Willamette Pass revealed that practically all air dispersal took place in the motile larva stage. Out of 271 chermes counted on 15 slides, only 10 were eggs. Considering the difficulty experienced in trying to remove crawlers from infested material by hand, it is apparent that dispersion through the air is a normal means of dissemination.

At Willamette Pass, three slides were lined out in a westerly direction from a moderately-heavy bole infested alpine fir. One was placed three feet from the base of the tree, the second 18 feet away, and the third 40 feet away. After a two week period of prevailing westerly winds, the first plate revealed 15 chermes, the second 4 chermes, and the third none. An easternly wind prevailed the next two weeks, during which time the number of crawlers on the infestation tree increased. A check at the end of this period showed the first slide to have 90 chermes on it. The second plate revealed 18 chermes and the third 7 chermes.

Slides set in clearings up to 80 feet away from the nearest surrounding infested trees, almost consistently exhibited three to four crawlers a week. However, slides placed at the base of bole-infested trees showed that the great majority of chermids leaving the host fell within a few feet of the base of the tree. On stand edges and ridge tops the larvae dropping directly from the bole could be an important factor in long range dispersion, although their significance is probably negligible when the infested trees are within rather extensive stands. Long-range dispersion is more likely attributable to crawlers that leave the bole infestation for the upper crown, where they can be swept into the wind. Dispersion in this manner is suspected of being especially effective in the late summer and early fall when localized convection storms are a common feature in our region.

Another function that vaseline slides were supposed to perform was to give some numerical indication of the chermes population present in infested areas exhibiting no bole attacks. Fifteen slides distributed in two different areas of the Lewis River infestation failed to reveal any sign of chermes. Either there was no attempt on the part of the insects to disseminate, or the number of chermes in the air was so negligible that they were missed.

Bole Infestation Patterns and their Possible Relationship to Host Resistance

Undoubtedly there are several factors that together account for host resistance or susceptibility to the balsam woolly aphid. One factor may predominate but it could be compensated by the addition of several others. However, if there is one main factor accounting for resistance or susceptibility, its discovery would greatly aid the solving of aspects of the chermes problem. In this section, the writer intends to relate some observations on bole infestation patterns and briefly speculate on their possible relationship to host resistance.

It was observed that bole infestations extend just so far up a tree and no farther. This was true with every host species observed. At the same time, many trees exhibited bole attacks extending all the way to the ground. A suggested answer for this pattern is that beyond the preferred areas the bark is either too smooth or too rough. It is also possible that host maturity might be a factor. Several trees in the Wind River Arboretum belong to species known to be susceptible to chermes. Their bark appears to be suitable for attack, yet they exist in close proximity with infested trees and exhibit only occasional signs of chermes attack. This seems to suggest that the uninfested trees have not yet become old enough to be susceptible.

If it is true that a tree must reach a certain age before it becomes susceptible, then the base of the tree, being the oldest portion of the host, would be the first to become susceptibly mature. At that point on the host, chermes production would exceed mortality. The greater the difference between production and mortality, the greater would be the population density. As the infestation proceeds up the stem towards the younger portions of the tree, population density should decrease as mortality approaches production. Roughly, that appears to be what happens. However, observations suggest that in the upper part of the stem, infestations actually exist where mortality exceeds production. A possible reason for this is that no susceptible species really has a period in its life when it is completely resistent to chermes. It is only the degree of susceptibility to which is referred.

Increased percentage of chermes survival is probably not the reason why visible infestations occur on the less susceptible portions of the host. More likely the infestations reflect a tremendous number of insects trying to establish themselves. Thus, when mortality exceeds 99 per cent of production, chermes must be supplied from an outside source producing in over abundance. In the case mentioned above, the lower portions of the bole infestations are probably supplying the upper portions. A similar example would be the case of the normally resistant reproduction and suppressed trees becoming gouted when growing as understory in heavily infested stands.

The upper limits of a bole infestation are possibly determined by the numerical supply of outside sistens and the availability of suitable bark. Beyond a certain point on the main stem, the bark becomes too smooth to satisfy settling sistens. On subalpine and European silver fir, significant populations never seem to develop on those portions of the trees that are younger than eight years. When competition for space becomes a factor on the main stem, the sistens apparently search out the roughened areas under the limbs and the annual nodes.

The lower limits of bole infestations seems to depend entirely upon the condition of the bark. Slow growing trees typically develop thick, plated bark at the base. Because of this, they never have infestations extending all the way to the ground. Some do not develop bole infestations at all, evidently because of undesirable bark covering the entire susceptible area of the tree. These would be especially slow-growing trees. Slow growth of this type could be caused by genetic variability or a variety of environmental conditions. When whole stands exhibit such slow growth, the multitude of environmental conditions causing it are lumped together under the term "poor site". Unfortunately, this suspected correlation between poor site and resistance to bole infestations can not be proved until someone devises a method for site determination for true fir.

CHERMES DISTRIBUTION AND HOST SUSCEPTIBILITY

Distribution

At the beginning of the season, plans were made for the writer to make a regional survey of the balsam woolly aphid infested area. A special effort was planned to determine the northern and southern boundaries of the infestation in the Cascades. Subsequently it was found that the survey section had a crew available for the project. Their findings will be available in another report.

Susceptibility

Although the writer did not make a widespread survey, several species of *Abies* heretofore unrecorded as hosts of *C. piceae* in the Pacific Northwest were recorded. A brief review of the literature indicates that one species, *Abies pinsapo* Boiss, has never been recorded as a host species of balsam woolly aphid. Table 2 lists all the susceptible species observed to date in Oregon and Washington, and where they were found.

Observations on apparent susceptibility and nature of gouting were scheduled for several species in the Wind River Arboretum. However, owing to the severe damage that has already occurred there, only one species, *A. lasiocarpa*, still had trees remaining in good enough condition to merit study. On trees of this species, 12 new shoots were tagged. Microscope examination of each shoot was used to determine the stage and number of sistens present. The number of developing buds on each shoot was also recorded. Six of these shoots were later photographed; repeat photographs will be taken as gouting develops. It is hoped that the data derived will supply some information on the rapidity with which buds are inhibited, the stage of chermes causing gouting, and the nature of gouting as correlated with the number of infesting sistens and developing buds on the attacked shoots.

Table 2.-*Abies* species observed in the Pacific Northwest to be attacked by *C. piceae*

Species	Location
Abies amabilis	Coast & Cascade Ranges, Ore. & Wash.
A. lasiocarpa	Cascade Range, Ore. & Wash.
A. procera	" " " "
A. grandis	Lowland valleys, Ore. & Wash.
A. alba	Wind River Arboretum, Hemlock, Wash.
A. pinsapo	" " " " "
A. balsamea (L.) Mill.	" " " " "
A. arizonica Lemm.	" " " " "
A. fraseri (Pursh.) Poir.	" " " " "
A. siberica Ledeb.	Hoyt Arboretum, Portland, Ore.
A. cephalonica Lud.	" " " "
A. firma Sieb. and Zucc.	" " " "
A. concolor (Gord. and Glend) Hoopes	" " " " and Forestry School Arboretum, Corvallis, Ore.

TREND PLOT STUDIES

Three trend plots of 100 trees each were established in 1954 by the Pacific Northwest Forest and Range Experiment Station in mature Pacific silver stands in southwest Washington. The objectives for establishing the plots were to:

1. Determine the rate of stand decline and mortality of individual trees and stands showing various degrees of infestation.
2. Develop a marking guide to assist in establishing cutting priorities for infested stands.
3. Provide some volume data on losses already incurred.
4. Determine deterioration rates of aphid-killed Pacific silver fir.

Methods and Procedures of Plot Establishment and Evaluation

Every tree was tagged and its DBH and crown position (Dominant, Co-dominant, Intermediate, and Suppressed) recorded. Annually, each tree has been given a rating of one of the following over-all damage conditions: (1) full vigor, (2) slightly weakened, (3) moderately weakened, (4) seriously weakened, and (5) dead. Each year until 1957 the crown was divided into quarters and each quarter was rated as to intensity of gouting, top and branch kill, old foliage color, old foliage density, amount of new foliage, and presence of other insects such as bark and ambrosia beetles.

Some modifications in the amount and type of data taken were made before the 1957 examinations. General over-all ratings are still given to each tree, but detailed data such as "lack of new foliage" etc. are recorded only on the first 34 trees of each plot. Evaluations were further simplified by applying the ratings only to each third of the crown rather than the old method of evaluating each quarter. The character of "old foliage color" was felt to be unrelated to the problem and was therefore dropped from the ratings. These modifications were made to speed-up, simplify, and provide greater accuracy to the evaluations.

Host Susceptibility and Decline

Host decline and mortality trends in stands having a large number of bole attacks differ quite markedly from those infestations characterized solely by gouting in the crown. Data from one type of infestation should not be applied to the other. The stands on the trend plots are quite typical of the crown type of infestation in which the trees that die usually are damaged by severe gouting and a continuing period of crown deterioration. All the trees were alive when first tagged and since then only four have died. Many, however, were in poor condition initially and up until last year showed a general decline. Evaluations in 1956 revealed some recovery in 11 per cent of the trees. This year's data is even more encouraging. Recovery over the initial ratings occurred in a little more than 30 per cent of the trees. Tables 3 and 4 summarize the information recorded on the three plots.

Analysis of the data gathered thus far strongly suggests that the largest trees in the stand suffer the greatest chermes damage. Trees in the dominant crown class account for only 26 per cent of the total number of plot trees, yet for the last two years 55 per cent of the dead and seriously weakened have occurred in that class. It also appears that the largest trees are the slowest to recover. Average numerical condition of trees show that on almost every plot, each crown class except the dominant has improved beyond the initial 1954 ratings. It is also interesting to note that while the stands exhibited considerable improvement over the 1956 ratings, the average diameter of all the trees dead and seriously weakened actually increased.

Further indications on the correlation between host size and damage intensity are supplied by plot seven. It has the largest average tree diameter and the highest numerical rating. Conversely, plot six, which has the smallest average stem diameter, has the lowest numerical value. A condition that may be affecting this relationship, however, is that plot seven has been selectively logged for the inter-mixed Douglas-fir. Since open-grown and stand-edge trees seem to be more susceptible to damage than others, it may be that the cause for greater damage is due to the open nature of the crown canopy.

Table 3.-Summary of Pacific silver fir tree decline on trend plots.

		Plot 4	Plot 5[1]	Plot 6	Total
Total Number of Trees by Crown Class:	DOMINANT	31	7	48	86
	CODOMINANT	41	50	30	122
	INTERMEDIATE	24	39	22	85
	SUPPRESSED	4	1	0	5
	Subtotal	100	97	100	298
Total Number of Trees Dead and Seriously Weakened by Crown Class:					
	DOMINANT	7	2	17	26
	CODOMINANT	3	3	8	14
	INTERMEDIATE	2	0	4	6
	SUPPRESSED	1	0	0	1
Per Cent of Trees Dead and Seriously Weakened by Crown Class:					
	DOMINANT	22.6	28.6	35.4	30.9
	CODOMINANT	7.3	6.0	26.6	11.6
	INTERMEDIATE	8.3	0	18.2	7.1
	SUPPRESSED	25.0	0	-	20.1
Average DBH of All Trees:		20.0	18.6	23.6	20.7
Average DBH of All Trees Dead and Seriously Weakened:	1956	23.6	23.8	27.4	24.8
	1957	22.4	27.0	26.5	25.4
Average Numberical Condition of Trees by Crown Class:[2]					
	DOMINANT				
	1954[3]	2.6	2.3	2.3	2.4
	1956	3.1	3.3	3.3	3.2
	1957	2.6	3.0	2.8	2.8
	CODOMINANT				
	1954	2.2	2.0	2.2	2.2
	1956	2.5	2.7	2.9	2.7
	1957	1.9	2.1	2.6	2.2
	INTERMEDIATE				
	1954	2.1	1.9	2.1	2.2
	1956	2.1	1.9	2.6	2.6
	1957	1.5	1.2	1.8	2.0
	SUPPRESSED				
	1954	2.0	3.0	-	2.2
	1956	2.2	3.0	-	2.6
	1957	2.0	2.0	-	2.0
Total Average Numerical Condition:	1954	2.28	1.98	2.23	2.16
	1956	2.56	2.37	3.03	2.66
	1957	2.03	1.82	2.55	2.14

[1] Three trees lost to windthrow.

[2] Key: 1, Full vigor; 2, Slightly weakened; 3, Moderately weakened; 4, Seriously weakened; and 5, Dead.

[3] Initial rating.

Table 4.-Decline and recovery of Pacific silver fir expressed as a percentage of the total number of trees in the damage class four years previously.

Original Crown Condition	No Change	Decline 1 Class	Decline 2 Classes	Decline 3 Classes	Recover 1 Class	Recover 2 Classes
Full Vigor	64.0	32.0	0	4.0	-	-
Slightly Weakened	41.3	14.3	8.4	0.5	35.2	-
Moderately Weakened	37.2	32.6	2.3	-	18.6	9.3
Seriously Weakened	68.7	12.5	-	-	12.5	6.3
Total	43.8	18.3	6.3	0.7	28.4	1.7

One of the most unexpected revelations brought forth by this study was that silver fir can withstand a tremendous amount of damage and still live. Mature trees have been observed to sustain life up to four years with most of the upper crown completely devoid of any green foliage. Several of the most seriously weakened trees showed signs of recovery in 1957. Plot evaluation showed that a little over 31 per cent of the 64 trees classified as seriously weakened in 1956 had recovered at least one class. Recovery was even greater in the moderately weakened class. Better than 47 per cent of the 93 trees classified in 1956 had improved at least one class and often two classes.

The first visual indication of tree recovery is the production of new growth in the top portion of the crown. On badly damaged trees the new foliage usually appears next to the main stem, several feet above the nearest green needles. The result is that the recovering part looks much like a green ball balancing on, or being skewered by the dead top. With the less severely damaged trees, recovery is not quite so striking. The new growth appears more like a green cap or umbrella resting directly on top of a rather aborted, often chlorotic-appearing, portion of the upper crown.

Encouraging as this information may seem, it still can not be accepted as the positive trend until a few more years of data has been collected. Furthermore, the answers can be applied only to Pacific silver fir with crown infestations. Trees with bole infestations usually succumb quickly. The plots installed in these types of infestations by Weyerhaeuser Timber Company will probably reveal the differences; results are available in reports of that company.

RECOMMENDATIONS FOR FURTHER STUDY

It is recommended that the present study be carried on in much the same general areas of investigation as in 1957. These include: (1) the introduction of more foreign predators, (2) the identification and evaluation of native predators, (3) study of the biology and behavior of the balsam woolly aphid, and (4) the effect of chermes on its various hosts. New studies planned are: (1) Biology and behavior of native and established imported predators, and (2) evaluation of effectiveness of established foreign predators. An ecological study of the true firs, particularly Pacific silver fir, is also urgently needed.

Particular aspects of the biology and behavior of predators that need studying are:

1. Life history
2. Feeding habits
3. Searching ability
4. Rate of dispersal
5. Environmental resistance factors.